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Fisheries and Oceans Canada

Five-Year Research Plan (2008-2013)

Canada

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1.0 Preamble

The focus of this document is the development of a DFO Science Five-Year Research Plan, the first of its kind for DFO. The basis for this plan can be found in the Science Framework for the Future and the Five-Year Research Agenda, neither of which will be discussed in detail but need to be consulted to fully appreciate the context of this Research Plan. This document is not a comprehensive plan describing all research conducted within DFO Science. For example, research in support of stock assessment is not specifically described in this plan but most aspects of stock assessment research fall under the Five-Year Research Agenda and will continue to represent a significant portion of DFO's science advice.

This plan provides a rationale for **what** research is conducted in support of priority areas, especially ecosystem-based management, and **how** this research will be delivered to ensure federal and departmental priorities are addressed while accounting for regional differences. This living document will guide DFO Science through the next five years. Twenty initiatives are underway within DFO Science to ensure the department can deliver on priorities outlined in the Five-Year Research Agenda. It is expected that both the Research Agenda and this accompanying Research Plan will be revisited and revised accordingly in five years to ensure changing priorities are adequately addressed. Further, the twenty initiatives will require realignment of regional resources to ensure priorities are addressed.

This document is intended to provide DFO Scientists and Science Managers with an overview of each of the 20 key Science initiatives and show how they relate to research priorities and each other. This document also shows our clients, partners and Canadians our commitment to ecosystem-based research. Finally, this document outlines a way forward for DFO Science within the current environment of change and demonstrates how a multidisciplinary approach is the only way forward. An integrated and coordinated approach in support of priorities, including new delivery mechanisms, will maximize the benefit of our research programs, a cornerstone of DFO Science.

In summary, the plan articulates how DFO Science will address research in support of priorities over the next five years, using the newly developed Ecosystem Research Initiatives, Climate Change Science Initiative and Centres of Expertise.

2.0 Context

2.1 Background

The DFO Science program is multidisciplinary and comprehensive. In support of fisheries, aquaculture, oceans and habitat management, and maritime safety, DFO Science performs five primary functions: research, monitoring, data management, scientific advice, and products and services. Limited resources and increased demands for increasingly specialized products and services challenged DFO Science program

capacity to effectively support federal and departmental priorities. Thus, DFO Science is continually re-aligning itself to ensure its program is relevant, effective, affordable, and valued. Creating a balanced Science Program ensures long-term stability to support decision and policy making through monitoring and data management activities while maintaining flexibility to respond to evolving demands is accomplished through research, scientific advice, and products and services. A coherent Research Plan, which is a key component of our Science Framework for the Future, will ensure DFO Science targets research in support of the department's strategic plan.

2.2 Strategic Directions

Ecosystem science is the foundation for the science needed to support the integrated management of diverse human activities and is needed to inform departmental policies and management practices. Our Ecosystem Science Framework provides an effective and comprehensive approach for identifying, monitoring, and interpreting trends important to ecosystem sustainability and integrating knowledge about the effects of human activities on ecosystem components. This Research Plan supports ecosystem science through its 20 components and their connections.

Our Five-Year Research Agenda provides DFO Science direction to develop new knowledge and methods in support of the diverse demands for advice required to support policy and decision making, especially integrated or ecosystem-based management. In addition, this Agenda identified ten priority research areas that are considered essential to addressing federal and departmental priorities over the next five years. The Research Plan presented here outlines the research that DFO will undertake over the next five years in pursuit of priorities identified in the Research Agenda and presents a pathway to link DFO Science delivery mechanisms to these priority areas. Some existing resources and activities will need to be realigned to ensure proper support of the Research Agenda.

Our Science Human Resource Strategy was designed to reflect the philosophical and cultural shift required to change the make up of the DFO Science program workforce since implementing ecosystem-based science is more than redistributing limited resources. This strategy provides DFO Science managers with key tools to realign and refocus research in support of departmental and federal priorities.

Our Strategic Science Outreach Strategy ensures that scientific advice is fully considered in policy development and decision making and provides direction on how to best disseminate information to general audiences so as to build public confidence and trust in DFO Science.

DFO Science, like other federal and international agencies, does not have the capacity to develop and retain all the necessary expertise, experience and resources to support integrated management alone. Therefore to realign the DFO Science program we must effectively draw on the necessary expertise wherever it resides. DFO Science will partner with experts and collaborate with other agencies whenever possible, both nationally and internationally, including other DFO Sectors, academia, aboriginals,

industries, non-governmental organizations and other government agencies. Collaborative approaches and partners will be critical to the successful delivery of this Research Plan. Ecosystem Research Initiatives, the Climate Change Science Initiative and DFO Science Centres of Expertise each use this collaborative approach to address longer term research issues that could not otherwise be addressed.

3.0 Basis for the Five-Year Research Plan

3.1 Objectives and Goals

This Research Plan builds upon the foundation outlined in the Five-Year Research Agenda which provided strategic direction on how to focus effort and resources to federal and departmental priorities. The Research Plan will show how four of the priority areas will be addressed primarily through Ecosystem Research Initiatives (ERIs) that address regional research priorities including: Fish Population and Community Productivity, Habitat and Population Linkages, Climate Change / Variability, Ecosystem Assessment and Management Strategies. The remaining six priority areas will be addressed primarily by national Centres of Expertise (COEs) including: Aquatic Invasive Species, Aquatic Animal Health, Sustainability of Aquaculture, Ecosystem Effects of Energy Production, Operational Oceanography, and Emerging and Enabling Technologies for Regulatory and Policy Responsibilities. However, it should be noted that both Ecosystem Research Initiatives and Centres of Expertise will help the department address more than one priority area. Climate Change is a timely and topical issue for DFO and to ensure the department can deliver on climate change related issues, DFO Science has established the Climate Change Science Initiative (CCSI). Each of the Ecosystem Research Initiatives, Centres of Expertise and the Climate Change Science Initiative are strongly influenced by the Ecosystem Science Framework and will produce new knowledge and improve existing knowledge that will be needed for integrated management and demonstrate a strong commitment to research to our clients and partners. A brief overview of each is provided below.

3.2 Ecosystem Research Initiatives (ERIs)

Although geographically distinct with different stressors, each ERI will serve as a pilot for DFO's ecosystem-based approach by focusing on regional research priorities. This will allow integrated research on a particular ecosystem with predefined geographical boundaries and the knowledge gained from large-scale ecosystem studies will allow the development and testing of tools required to manage human activities within our aquatic ecosystems. Before we can begin to understand how human activities might impact ecosystem components we need to first understand how ecosystems function and how they respond to drivers or perturbations. Thus, the general themes within each ERI include: 1) understanding ecosystem processes, 2) understanding the impacts of climate variability, and 3) developing tools for ecosystem-based management. DFO Science will ensure delivery of scientific advice consistent with DFO and government needs by

developing standardized objectives and ecosystem indicators that can be shared with client Sectors. As new entities, ERIs will produce new scientific research that will be communicated to decision makers and the international community in the form of advice, primary publications, conference presentations, etc. In some cases the work of COEs may be interlinked with broader objectives under ERIs (e.g., assessment of risk from offshore oil and gas facilities on the Georges Bank by COOGER will provide support to the Gulf of Maine and Newfoundland Shelf ERIs). In addition, status reports and data required for integrated management will be produced for internal audiences allowing DFO Science to provide consistent, timely, integrated science-based advice to all DFO clients. The large volume of data expected to be generated by these initiatives highlights the need for integrated databases that adhere to national standards.

3.2.1 Newfoundland Shelf (NLS)

The geographical extent of this ERI encompasses the Newfoundland and Labrador Shelf, including the southern Labrador shelf, northern Grand Banks, and the Grand Banks proper. The Newfoundland and Labrador Region's ERI aims to develop and test monitoring tools and methods that will improve information on forage fishes, non-commercial species, major benthic components, and trophic interactions and to identify and track the main pathways of energy in the system to allow trophodynamic modeling of core components. An operational understanding of the Newfoundland Shelf ecosystem will be gained by identifying energy pathway and fluxes, how they are regulated and environmental drivers of change. By integrating monitoring activities into a robust framework through dynamic modelling of key trophic relationships and collection, analysis and integration of ancillary information, including potential effects of temperature and community dynamics that will allow hypothesis testing, the primary goals of this ERI will be accomplished. Research activities conducted within the context of this ERI will complement current, ional research and monitoring activities. The additional work proposed within this ERI will require realignment of resources to ensure program delivery and leveraging with external partners will focus research in priority areas.

3.2.2 Gulf of Maine (GOM)

The Maritimes Region's ERI is the Gulf of Maine Area, including the Gulf of Maine, Georges Bank, the Bay of Fundy and the western portion of the Scotian Shelf. Previous research in this area has documented changes in species and community composition, declines in some commercial species and threats due to invasive species. It is unclear what the cumulative impacts of human activities or the impacts of climate change will be on this ecosystem. The goal of this initiative is to augment current research efforts that provide the scientific basis for biodiversity, productivity, and habitat-related objectives for an ecosystem approach to management in the Gulf of Maine Area. This will be accomplished by focusing activities around three major themes: 1) influence of climate change on the oceanography and ecosystems of the Gulf of Maine and Georges Bank region, 2) spatial patterns in benthic communities, and 3) quantification of the impact of ecosystem interactions on harvest rates and dynamics of commercially targeted (and non-

targeted) species. The influence of climate change will be investigated by characterizing the link between the oceanography of this ERI within the broader climate context and research aimed at predicting ecosystem impacts under future climate scenarios. The second and third themes will use a variety of modeling techniques to characterize and better understand ecosystem responses to specific perturbations. Each theme will contribute to the development of tools for integrated management of this ERI as well as scientific methods for assessing cumulative effects and approaches to the practical implementation of ecosystem-based assessment. There are a number of research projects underway within the Gulf of Maine Area, including DFO and U.S.-based projects. Linkages to these projects will be established and linkages with other ERIs / COEs will be pursued. Consultations have been initiated with clients (Fisheries and Aquaculture Management, Oceans and Habitat Branch) to define integrated management priorities.

3.2.3 Northumberland Strait (NOS)

The geographical extent of this ERI is the Northumberland Strait, located in the southern Gulf of St. Lawrence between Prince Edward Island and the provinces of Nova Scotia and New Brunswick. An important social and economic area for generations, this area recently has experienced changes in the abundance and distribution of key species. Whether due to the cumulative effects of several stressors or the impact of larger-scale processes, there is a desire to better understand the causes of degradation and associated resource decline. Research conducted within Gulf Region's ERI is designed to align with DFO's goals of ensuring healthy and productive aquatic ecosystems and to support sustainable fisheries and aquaculture in the Northumberland Strait while addressing some of the key issues identified in the recent ecosystem overview report. New projects within this ERI will focus on the physical, biological, and human systems. In addition, ongoing research activities and monitoring programs will enhance the proposed activities within this ERI. There are four major themes within this ERI including: 1) planning, administration, publishing, 2) modeling oceanographic, physical and chemical processes and interactions, 3) understanding biological processes and developing indicators, and 4) managing and providing information and communication, including advice for integrated management. External partners or collaborators have been identified and linkages with COEs have been established.

3.2.4 Lower St. Lawrence Estuary (LSLE)

Quebec Region's ERI is the Lower St. Lawrence Estuary (LSLE), which extends from the mouth of the Saguenay Fjord downstream to Pointe-des-Monts, Quebec. There is intense tidally-induced mixing between freshwater and saltwater and upwelling at the head of the Laurentian Channel, both of which contribute to the high productivity of this ecosystem. The LSLE is subject to a variety of human activities and their associated stressors that could affect physico-chemical and biological processes within this area. This ERI aims at providing integrated peer-reviewed advice on conservation priorities identified by DFO clients. Multidisciplinary research and monitoring programs will be implemented to address scientific issues and gaps related to these priorities. The LSLE ERI will allow the region to coordinate existing, and initiate new projects, to study the

interactions between various environmental stressors that affect local processes and productivity in the LSLE. In addition to supporting other research activities within this ERI special initiatives are planned to identify coastal critical habitats of the St. Lawrence beluga population and pelagic forage species in the Lower St. Lawrence Estuary. Research will be targeted at priorities identified in the Five-Year Research Agenda and linkages with COEs will be made as needed. In addition, acidification and hypoxia are becoming a major concern in the LSLE, thereby creating a strong linkage between this ERI and the CCSI.

3.2.5 Lake Ontario (LO)

The Great Lakes ERI encompasses Lake Ontario, with emphasis on nearshore coastal areas. The Lake Ontario ecosystem is impacted by upstream, proximate and downstream factors. Human development, hydropower generation, international shipping and climate change collectively impact the lake at an ecosystem scale; however, these impacts are greatest in nearshore coastal areas that represent the interface between the lake and human development. The nearshore environment is affected by water level management, has been invaded by a number of aquatic invasive species and is the shallow warm water area of the lake most likely to be affected by temperature and precipitation effects of climate change. Nearshore habitats also serve as nursery and feeding areas for many Great Lakes fishes and native biodiversity and the productivity of fish populations are linked to these areas. It is unclear how the cumulative impacts of multiple stressors will affect the function of the nearshore environment in the Lake Ontario ecosystem. The goal of the LO ERI is to build on research and partnerships in Lake Ontario to: 1) evaluate how the nearshore coastal area contributes to the function of the whole lake, 2) assess the sensitivity of the nearshore to cumulative impacts from multiple stressors, and 3) predict how the nearshore will respond to projected future conditions. While this ERI will focus on Lake Ontario, it is expected that the results and understanding generated will help with the integrated management of the other Great Lakes as well as inland waters. Research conducted within this ERI will link with ongoing activities in Lake Ontario, will complement the research priorities of COEs (e.g., CAHR, CEARA, CHIF), and will provide the foundation for linking with future climate change research (e.g., CCSI).

3.2.6 Beaufort Sea Shelf (BSS)

Central and Arctic Region have identified an arctic ERI in the Beaufort Sea, Western Arctic that includes the proposed Tarium Naryutait Marine Protected Area. This is a significant area for Inuvialuit people for subsistence harvest of fish and marine mammals and this ecosystem faces a number of new human-mediated stressors (e.g., oil and gas exploration, climate change). Sea ice changes, species shifts in abundance and distribution, diseases in marine mammals and fish have already been identified. The goal of this ERI is to allow DFO to address the cumulative impacts of multiple stressors on the Beaufort Sea Large Ocean Management Area (LOMA) using an integrated, ecosystem-based approach. To achieve this goal there are several major themes that will be explored including: fish as pivotal ecosystem components, factors controlling seasonal distribution,

stock delineation and health of marine mammals, lower trophic dynamics of the Beaufort Sea LOMA, primary productivity in the Beaufort Sea, including implications of a changing climate, and developing approaches to integrate ecosystem components in order to assess cumulative impacts in the Mackenzie Estuary. The high cost of working in the Arctic will require realignment of existing resources but external funding will allow multi-year work planning and partnerships/collaborations. Strong linkages exist between this ERI and the CCSI.

3.2.7 Strait of Georgia (SOG)

This ERI focuses on the Strait of Georgia between Johnstone Strait and the mouth of Juan de Fuca Strait. The area is the focus of many resource management and scientific issues (e.g., fisheries, aquaculture) and this marine ecosystem is facing significant stresses/threats (e.g., climate change, invasive species). Pacific Region's ERI is designed to align research activities with the departmental goals of ensuring a healthy and productive aquatic ecosystem in the Strait of Georgia, and to support sustainable fisheries and aquaculture in the Strait by considering alternative, future scenarios of what the Strait of Georgia might be like in 2030. The three major themes of this ERI include: 1) understanding how this ecosystem works, 2) identifying drivers of change most likely to determine future conditions, and 3) analyzing future responses of the system under these influences. Research within this ERI uses hypothesis testing in relation to three major research priorities: 1) Productivity: what controls productivity in the Strait of Georgia?; 2) Timing: how important are the mismatches in the timing of physical and biological processes within the Strait of Georgia to ecosystem functioning?; and 3) Ecosystem Resilience: what properties/characteristics of the Strait of Georgia ecosystem provide resilience against major disruptions and collapses of the system?

3.3 Climate Change Science Initiative

DFO recognizes climate change will affect many aspects of its Science activities and that understanding and predicting climate change and its impacts is important. Thus, CCSI is designed to focus on national research priorities including improved predictions of climate change in Canadian waters (both marine and fresh); improved understanding of potential impacts on aquatic ecosystems; anticipate emerging issues that have not been adequately researched, and work with other sectors to identify potential socio-economic effects. As a nationally coordinated program, CCSI will complement the regional ERIs and establish linkages with research conducted within COEs. The goal of CCSI is to establish a program that will maintain core expertise and allow the development of national and international partnerships. Research aligned with three major themes will ensure CCSI will meet its expectations including: 1) understanding the role of oceans in regional climate, 2) assessing impacts of climate change on ecosystem composition, structure and function, and 3) investigating emerging issues that could impact ecosystem health. Initial prediction and scenario projects for the CCSI will focus on downscaling climate change scenarios for ocean-ice variability in the three basins (Atlantic, Pacific

and Arctic) while efforts on emerging issues will focus on hypoxia and ocean acidification.

3.4 Centres of Expertise (COE)

DFO Science created Centres of Expertise to address national research priorities identified in the Five-Year Research Agenda. There are two types of COEs within DFO Science: virtual Centres and geographic Centres. Virtual COEs are designed to bring together expertise and infrastructure on an as-needed basis to integrate experts and expertise to focus on specific, priority issues or topics. In contrast, geographic COEs have human, financial and infrastructure resources concentrated in a specific location that allows specialized program delivery through concentrated analytical expertise and research capacity while avoiding costly duplication of experts and equipment. The majority of DFO Science COEs (9 out of 12) are virtual with Directors distributed among Science research facilities across the country.

3.4.1 Centre of Expertise for Aquatic Animal Health and Research Diagnostics (CAAHRD)

Although the Canadian Food Inspection Agency (CFIA) is the lead agency for the National Aquatic Animal Health Program (NAAHP), DFO is responsible for providing diagnostic and research support. This virtual COE will provide consistent and scientifically robust delivery of aquatic animal health diagnostics and research in support of NAAHP, research diseases of highest regulatory significance through the nationally coordinated Aquatic Animal Health Laboratory System that includes the Gulf Fisheries Centre, Moncton, NB; the Pacific Biological Station, Nanaimo, BC; and the Freshwater Institute, Winnipeg, MB. CAAHRD has three primary priorities: 1) diagnostic methods, 2) technology development, and 3) knowledge generation. This COE will develop and validate quality assured diagnostic methods for priority diseases, develop efficient and effective technology platforms in support of analytical procedures and diagnostic tests, and develop a sound scientific knowledge base in support of regulatory programs and risk-based management. Research priorities established in conjunction with CFIA include: viral strain differentiation and correlation to pathogenic significance, development and validations of diagnostic tools, disease transmission via product, carrier species, non-lethal sampling, processing effluent, decontamination procedures, and emerging disease investigation. As aquatic animal health issues expand, CAAHRD will provide the research and diagnostics required to protect Canada's seafood trade.

3.4.2 Centre for Aquatic Biotechnology Regulatory Research (CABRR)

This geographic COE located at the Centre for Aquatic Environmental Research (CAER) in Vancouver, BC has a mandate to enable, undertake and coordinate regulatory research related to aquatic organisms with novel traits and to provide scientific knowledge to inform their regulation, including risk assessment of transgenic fish. CABRR research is centred around several priorities including: development and

maintenance of regulatory research activities required to keep Canada at the forefront of this international effort and establish the knowledge and scientific basis for risk assessment and regulatory approval of genetically modified finfish, exploration of the breadth of effects arising from genetic modification of finfish, assessment of validity of experimental and modelling approaches currently utilized to generate empirical ecological risk assessment data for genetically engineered finfish, evaluation of the efficacy of methods for bio-confinement of transgenic aquatic organisms, provision of science knowledge to inform the scope of organisms to be captured within the biotechnology regulatory trigger, and communication and sharing of research results. CABRR will ensure transgenic finfish are available to support planned research activities, assess the morphological, genetic and behavioural effects of genetic modification, examine the interactions between genotype and environment and attempt to identify a suitable surrogate for transgenic fish in contained systems, examine multigenerational genetic interactions among transgenic and wild conspecifics, and assess the suitability of polyploidy as a bioconfinement approach for genetically modified finfish. This COE will continue to strengthen the existing regulatory research program while putting into operation a set of complementary and effective communication and information sharing activities to make the research effort readily accessible for regulatory advice, including risk assessments related to transgenic species.

3.4.3 Centre of Expertise for Aquatic Risk Assessment (CEARA)

This virtual COE was established in response to the need to meet national and international commitments to protect aquatic ecosystems from the threat posed by aquatic invasive species (AIS). The mandate of CEARA is to develop national standards for, and to provide guidance on, scientifically defensible biological risk assessment for AIS. Developing guidance documents and holding national workshops to educate practitioners on the risk assessment process will ensure this mandate is achieved. Also, CEARA will be responsible for identifying risk assessment priorities and tracking national risk assessments to provide science advice related to healthy and productive aquatic ecosystems and sustainable fisheries and aquaculture. CEARA has four priority areas: 1) to develop a national standard for conducting biological risk assessments of AIS, 2) to convene national workshops to educate practitioners on the risk assessment process, 3) to develop a process for prioritizing risk assessment needs, and 4) to coordinate the tracking of national risk assessments. Risk assessments and associated predictive tools being developed by CEARA provide essential information for DFO and others to understand the biological risk associated with specific AIS and/or their vectors and pathways. Recently completed risk assessments have focused on high priority species such as Asian carps, non-indigenous colonial and solitary tunicates, European green crab and Chinese mitten crab, northern snakehead and non-indigenous freshwater fish introductions. In addition to species risk assessments CEARA will be conducting vector risk assessments such as live food and aquarium trade and recreational boating. This COE will continue to provide advice on potentially high risk invaders such that managers and policy makers can use these results to inform preventative or mitigative measures for AIS.

3.4.4 Centre of Expertise on Marine Mammals (CEMAM)

Research within this virtual COE is strongly influenced by internal and external clients who need advice on harvest management, industrial impacts, and sensitive ocean areas. CEMAM meets these needs and provides strategic direction for marine mammal research within DFO by promoting the development of inter-regional, national and international collaborative research and monitoring programs, coordinating scientific input into policy development for marine mammal research and monitoring, increasing the visibility and profile of DFO's marine mammal science program, and promoting the development of partnerships with universities, co-management boards, NGOs and the private sector. CEMAM research is undertaken in all three of Canada's Ocean regions: the Atlantic, Arctic and Pacific. Four priority areas of research are conducted within CEMAM including: 1) population research, 2) understanding the role of marine mammals in marine ecosystems, 3) understanding the impacts of development on marine mammals, and 4) understanding aquatic animal health (e.g., marine mammals as ecosystem indicators). Some of the research activities within CEMAM focus on developing new assessment and population modelling approaches to meet the increasing demand for science-based advice on population productivity of marine mammals. Understanding the diet and trophic relationships of marine mammals and how these are influenced by environmental change will help develop ecosystem-based indicators. Research also is aimed at characterizing the spatial distribution of marine mammals in relation to industrial activities to develop best practice guidelines to minimize the impact on marine mammals and aimed at better understanding sources of mortality for marine mammals.

3.4.5 Centre for Environmental Research on Pesticides (CERP)

The mandate of this geographic COE located in Winnipeg, MB is to consult with the Pest Management Regulatory Agency (PMRA) and other federal departments to identify high priority research needs related to the environmental effects of pesticides on fish and fish habitat. In support of pesticide research, DFO is committed to conducting research and monitoring on high priority pesticides and to provide research summaries to PMRA in order to influence their regulatory decision making in favor of protecting fish and fish habitat. Following consultation, CERP then carries out effects based field and laboratory research to address these high priority issues and communicate results to regulatory bodies. This COE examines the potential effects of primary pesticides on wild fish and invertebrate populations. The three CERP priorities include: 1) consultation with PMRA to establish research priorities, 2) evaluation of the potential for mixtures of high priority urban use pesticides to impact reproduction, growth, survival and immune function in fish and invertebrates, and 3) compilation and communication of these data. Due to the consultative requirement, priority pesticides could change from year to year and it is possible CERP would need to develop new analytical methodologies. Current research on high priority urban pesticides (e.g., 2-4 D, Mecoprop, Glyphosate, Diazinon, Imidacloprid) includes field research to identify environmentally relevant concentrations of these pesticides and laboratory studies to provide scientifically defensible data on the impacts of these pesticides both in single and combination exposure experiments. Final reports are reviewed and communicated to PMRA.

3.4.6 Centre of Expertise on Hydropower Impacts on Fish and Fish Habitat (CHIF)

The mandate of this virtual COE is to facilitate research activities on environmental impacts of hydroelectric power generation on fish and their habitats while considering both existing facilities' operations and development of new small and large scale projects, including potential impacts on freshwater, estuarine and marine environments. CHIF will work to improve methodologies to assess impact and risk and to quantify the level of harmful alteration, disruption or destruction of the productive capacity of fish habitat and avoid net loss. In freshwater environments the primary priority is to improve decision-making on the impacts of hydropower operations in three research theme areas: reservoir creation, fish passage, and flow modifications. Both field research and modeling exercises are underway to address these priorities. In marine and estuarine environments the current priority is to develop a network of expertise. Changes to the natural patterns of freshwater inputs to estuaries and coastal waters due to hydropower production could have significant effects on circulation and mixing process, thereby impacting entire food webs. Characterizing the cumulative impacts of the hydropower industry in the marine environment will be a challenge for CHIF and research projects will be designed accordingly. For example, research is underway to characterize the carbon sources and trophodynamics of an estuary to better understand how habitat alteration due to hydroelectric generation in freshwater impacts downstream processes. CHIF is working on finalizing a five-year freshwater research plan and will work to establish collaborative agreements in support of implementing this plan. In addition, CHIF will support research into the development of new tools for managers and will work towards development of a marine research plan to complement their freshwater one.

3.4.7 Centre for Integrated Aquaculture Science (CIAS)

The Canadian aquaculture sector is expected to grow significantly in the coming years thereby increasing the demand for sound scientific information required to predict the ecosystem impacts from aquaculture operations. Further, there is a need to develop effective sampling and monitoring programs, including a variety of ecosystem indicators, to assess the environmental impact of aquaculture operations. The mandate of this virtual COE is to lead, facilitate, coordinate, and implement an inter-regional and nationally integrated DFO aquaculture research program that supports and enhances aquaculture development and management within Canada in accordance with relevant inter-regional and national priorities of DFO Science clients, and with a focus on an ecosystem-based management framework. This COE has four major priorities including: 1) identification and quantification of the ecosystem effects of finfish, shellfish, and plant aquaculture operations, 2) characterization and minimisation of disease / health interactions, 3) characterization and minimisation of environmental / ecological and interbreeding / fitness interactions between wild and cultured organisms, and 4) to facilitate the development of innovative solutions for increasing the productive capacity and competitiveness of the aquaculture sector in Canada, while minimising ecosystem interactions. Research will be directed towards filling knowledge gaps about assessing, monitoring and managing ecosystem impacts and to better understand the interactions

between cultured and wild organisms. The CIAS program is structured to maximize potential collaboration and partnerships with aquaculture stakeholders and minimize impacts on natural ecosystem functions.

3.4.8 Centre for Ocean Model Development and Application (COMDA)

Ocean modeling research and development is needed to support DFO's longer term and changing requirements. The mandate of this virtual COE is to develop a nationally coordinated and collaborative approach to ocean modelling and to undertake both research and development in modelling of the physical marine environment. Such models provide DFO with scientific knowledge to support marine applications and scientific advice for policy decisions related to those applications and allows DFO to maintain a high international profile for modelling tools and scientific knowledge for sovereign waters. The work of COMDA is focused on three major priorities: 1) to develop and improve large-scale atmosphere-ocean-ice coupled models to provide a framework for all scales of ocean modelling and to maintain Canada at the forefront in international ocean-climate research, 2) to develop and improve regional atmosphere-ocean-ice coupled models for regional applications and products, and 3) to develop small-scale marine models, geared towards site specific localities and targeted applications. Research activities will focus on global-scale data-assimilative coupled models for operational forecasts and improvement of regional-scale pre-operational high resolution circulation models. In addition, very high resolution and particle tracking models will be developed for nearshore environments where DFO has specific priorities (e.g., energy generation, aquaculture, etc.) and emerging issues (e.g., climate change influences on coastal waters and productivity). Integrated expertise, tools and resources through partnerships and collaboration will ensure the success of this COE.

3.4.9 Centre for Offshore Oil, Gas and Energy Research (COOGER)

COOGER is a virtual COE that works closely with internal clients, stakeholders and regulators to identify research priorities related to oil and gas production in Canadian waters. The mandate of this COE is to facilitate the development of coordinated research programs in areas of aquatic environmental and oceanographic research related to oil and gas activities and DFO mandates. However, recent advancements in marine technology and increasing energy demands have resulted in this COE expanding its mandate to address ocean renewable energy production (i.e., the potential extraction of energy from tides, currents, waves and offshore wind) in addition to oil and gas. COOGER has several priorities including: assessing environmental impacts from the discharge of drilling wastes and fluids from exploratory drilling and production operations, evaluating the potential risks from produced water discharges in Atlantic Canada, evaluating the impact of seismic noise on fish and invertebrate species, evaluating the impact of oil spills and develop remediation technologies and guidelines for their use, identifying and assessing sensitive sites, providing scientific data to evaluate the environmental consequences of offshore renewable energy development, and providing scientific advice, technology transfer and communication. Research activities are focused on the identification and assessment of potential impacts and risks associated with offshore

energy developments. This will allow improved science-based advice for environmental monitoring, regulatory guidelines, and energy policy. COOGER research is heavily leveraged with external funding sources but projects are peer-reviewed to ensure scientific quality and relevance to DFO's mandate. In addition, this COE maintains an analytical chemistry laboratory at the Bedford Institute of Oceanography (Halifax, NS) for analysis of hydrocarbons.

3.4.10 Laboratories of Expertise in Aquatic Chemical Analysis (LEACA)

This COE was established in 2007 with two geographical locations, the Institute for Ocean Sciences (Sidney, BC) and the Institut Maurice-Lamontagne (Mont-Joli, QC). LEACA provides / defines analytical chemistry protocols in support of DFO's scientific community and delivers precise and accurate sampling results associated with chemical research and monitoring projects. The primary priorities of LEACA are: 1) to provide expertise in analytical chemistry protocols, 2) to provide expertise in analytical chemistry for organic and inorganic elements and compounds, 3) to provide cost-effective and efficient analytical support, and 4) to support the achievement of DFO integrated and ecosystem aquatic research priorities identified in the DFO Strategic Research plan. To minimize duplication and redundancy, the two laboratories provide complementary analytical protocols on metals, dioxins/furans, organohalogens and other manufactured compounds and their residues as they appear in aquatic ecosystems. Further, this COE plays a critical supporting role relative to some other COEs that are research oriented and mandate driven via analytical support. For example, provided resource availability, LEACA should facilitate mandate delivery by both CERP and COOGER through analytical analyses of chemical compounds.

3.4.11 National Centre for Arctic Aquatic Research Excellence (N-CAARE)

Research supported by N-CAARE is diverse and this virtual COE works to enable and coordinate a wide variety of Arctic research programs. These research programs are delivered inter-regionally based on an expert network requiring high level coordination and planning to ensure current and future needs are met. Thus, N-CAARE's mandate is to enable, coordinate and undertake scientific research related to Arctic marine and freshwater ecosystems to support expanding legislation, the provision of new knowledge, and commitments to Northerners and Canadians. Currently, the priority for N-CAARE is the coordinated delivery of DFO International Polar Year (IPY) research programs while contributing to the development of ecosystem-based research programs and the use of innovative Arctic-specific technologies for monitoring / research, and contributing to the development of an integrated and balanced Arctic Research Program. Research is underway to characterize circulation patterns, freshwater inputs, ice dynamics, and ecosystem assessment tools. Additional research is investigating how climate change will affect the productivity of fish and marine mammal populations and the potential for energy production in the north. Following IPY activities, N-CAARE will develop an integrated research program for the Arctic that includes innovative Arctic-specific technologies and this COE will play a critical role in delivery of research in support of the Beaufort Sea ERI.

3.4.12 Center of Expertise on Aquatic Habitat Research (CAHR)

DFO is responsible for safe-guarding fish habitat and ensuring human use does not adversely affect it. However, any human activity in aquatic ecosystems has the potential to directly or indirectly affect fish habitat. It is recognized there is a need to develop a more strategic, integrated approach to delivering science-based habitat advice. Thus, this virtual COE, our most recent, will provide strategic leadership to prioritise and address science requirements in freshwater and marine environments and facilitate informed policy development at regionally applicable scales. CAHR will bridge regional issues with national habitat initiatives directed towards practical and applicable results. Research priorities for this COE include: quantifying human vs. natural influences on habitat, identifying, evaluating, developing and standardizing methods to link productivity and habitat, understanding the impacts of fishing gear on habitat, developing methods to identify and measure habitat impacts, assessing the efficacy of mitigation measures designed to protect fish and fish habitat, standardizing survey methodologies, and facilitating data and information sharing.

3.5 Linkages between CCSI / ERIs / COEs and the ten priorities identified in the Five-Year Research Agenda

With a national CCSI, seven regional ERIs, and 12 national COEs, the DFO Science program is well positioned to deliver research in support of departmental and Government of Canada priorities (Figure 1). It is clear that the CCSI / ERIs / COEs (rows) link to a number of priorities identified in the Research Agenda (columns). Further, it is important to remember that the CCSI / ERIs / COEs do NOT represent the full amount of research conducted by DFO Science. Compiling information on all DFO Science research activities or programs is beyond the scope of this document. However, DFO Scientists and Science Managers should be able to identify how their research, or the research they are managing, is contributing to the research priorities identified in the Five-Year Research Agenda. DFO Science recognizes that priorities have changed, and will continue to change, over time such that some research activities are no longer aligned to priority areas. This is expected and acceptable as a time-lag often occurs when research programs are realigned to meet current and future (emerging) priorities.

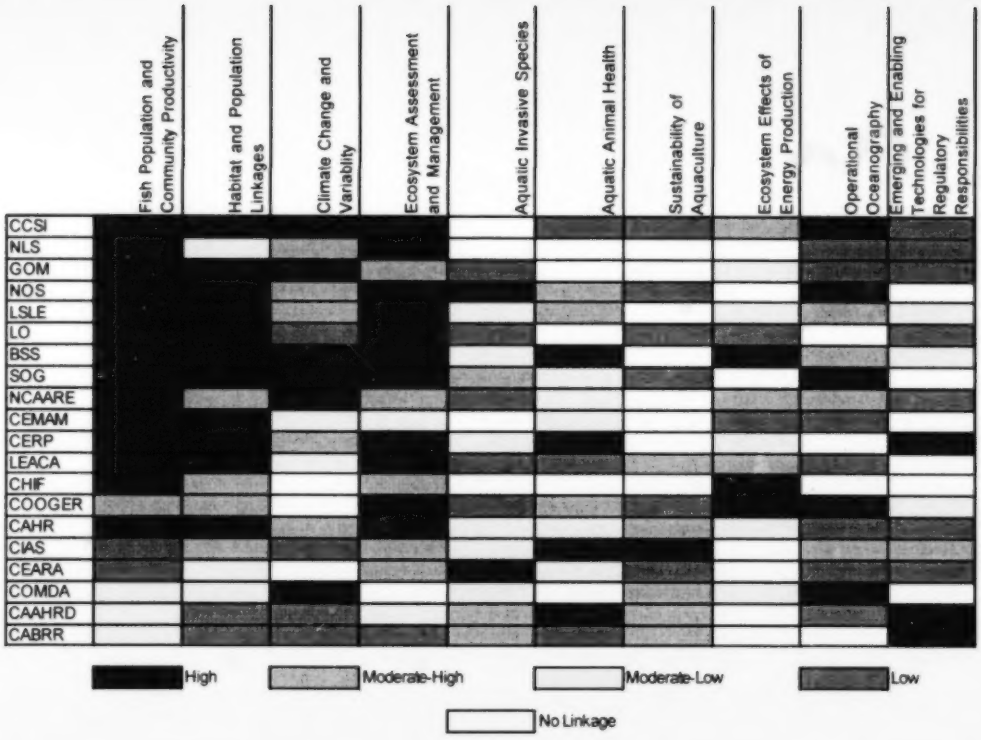

Figure 1: Relationship between the CCSI / ERIs / COEs and the ten priorities identified in the Five-Year Research Agenda. Abbreviations are found in Appendix A.

The CCSI and seven ERIs have their highest linkages to: Fish Population and Community Productivity, Habitat and Population Linkages, Climate Change and Variability, and Ecosystem Assessment and Management. This is very relevant given their goal of ecosystem-based pilots for integrated management of human activities. Relatively strong linkages also exist with Operational Oceanography as the CCSI and many ERIs will develop and utilize ocean models to advance a variety of research topics. Although several COEs have high linkages to these four priority areas as well, COE mandates and their respective research activities have higher linkages with other priority areas, thereby ensuring a balanced and efficient overall Research Plan. It is important to note that although no linkages sometimes exist between a specific DFO research priority and the CCSI or an ERI / COE, there is no priority area that is not covered. Further, there is a gradient under each of the ten DFO priority areas (columns) ranging from low or no linkage to high. This confirms that research within DFO Science is addressing departmental and Government of Canada priorities in a holistic way. Further, these areas of overlap identify potential areas of collaboration among COEs or between COEs and ERIs / CCSI. It is these areas of overlap that will need increased management attention to ensure research is integrated and harmonized while redundancy and duplication are

minimized. Also, recall that not all DFO Science research is captured in this matrix and that other research projects not shown contribute to priorities identified in the Research Agenda.

4.0 The Five-Year Research Plan

4.1 What Research Will Be Conducted Under this Plan?

DFO Science is committed to addressing priority areas identified in the Five-Year Research Agenda and providing advice and support for ecosystem-based management. Research priorities and timelines will be developed within each region but will be coordinated nationally to ensure a balance between regional and national research needs within available resources. DFO Science has developed the CCSI / ERIs / COEs to meet a diversity of research needs that will complement other Science functions. To ensure DFO Science continues to be relevant, effective, affordable, and valued, it will maximize integration of research activities and continue to focus resources and efforts on priority areas, especially when working closely with other Sectors, industry and academia.

The seven regional ERIs represent seven unique aquatic ecosystems across Canada, ranging from coast to coast to coast and representing both marine and freshwater. Each is influenced by a variety of biological, physical, chemical and human-mediated processes and our understanding of the functioning of each is limited. By conducting state-of-the-art research in each ERI, DFO Science will be able to provide science-based advice in support of ecosystem-based management of its aquatic systems both at regional (direct linkages) and national (indirect linkages) scales. By asking one or two research questions with standardized objectives/indicators that are the same in all ERIs it will allow comparison and evaluation of the robustness of analytical tools and approaches to data management. For example, research activities within each ERI will better characterize ecosystem structure and function (e.g., trophodynamic relationships). By identifying how stressors impact ecosystem dynamics, knowledge generated can be transferred to other aquatic ecosystems in Canada through provision of advice, including the development of frameworks/guidelines. Since ERIs have been designed as ecosystem-based pilots, it will be important to understand how science-based advice that is generated by ERI activities will meet ecosystem-based management objectives or needs, including feedback from our client Sectors. All data collected will need to adhere to regional and national data standards.

In addition to research conducted within each of the ERIs, there are national research activities within the CCSI and several COEs that also address fish, fish habitat, and assessment priorities. Specific projects will increase our understanding of ecosystem processes and functions, species and community composition, and trophodynamic relationships. Research will identify stressors and how they impact fish or fish habitat and subsequent productivity. This will allow a better understanding of ecosystem drivers and will permit the development and verification of ecosystem indicators. One key focus will be on the development of ecosystem forecasts, especially oceanographic forecasts.

These complex models will require the development and maintenance of research and monitoring programs that will collect and maintain the large volumes of data needed to parameterize and verify these data-rich models.

Although research conducted by COEs will contribute to ecosystem-based advice and understanding, their primary role is to conduct research in support of other departmental and federal priorities. For example, CEARA is developing and overseeing risk assessments of potential non-indigenous species that could negatively impact aquatic biodiversity and ecosystem health. CIAS is conducting cutting edge research on characterizing the interactions between aquaculture and the environment, thereby increasing our understanding of the response of these ecosystems to aquaculture impacts which will allow the aquaculture industry in Canada to grow in an environmentally sustainable way. The demand for energy is increasing and both COOGER and CHIF are conducting research to better understand the impact of energy production in Canada on aquatic ecosystems, both offshore and in freshwater and nearshore estuarine/marine environments. Finally, some research conducted by DFO Science COEs is in support of regulations such as the research conducted by CAAHRD, CABRR, COOGER and CERP, each of which provides regulatory advice to internal or external clients. The shift towards addressing these priority areas demonstrates the department's commitment to move into a broader ecosystem-based context where a number of competing demands are considered.

4.2 Is This the Right Research?

Each of the seven ERIs and the CCSI has an adequate scope to examine ecosystem-based questions. Research conducted in these pilots will significantly advance the ability of DFO Science to provide advice to multiple clients for integrated ecosystem-based management. Clearly, the proposed ERIs / CCSI represent a trade-off between scope and scale. Although it would be nice to do everything everywhere, this is simply not possible. DFO Science must utilize research conducted in these initiatives to derive advice for ecosystem-based management, including extension of findings beyond the specific ERI in which the research was initially conducted. Further, these are young initiatives that will evolve over time and so they must maintain some flexibility as specific integrated management tools and client requests have not been fully developed nor identified.

Recognizing that the COEs are not the only delivery mechanism for DFO Science, each of the 12 COEs will address priority areas of research at a national level by utilizing expertise wherever it resides. This approach will ensure coordination and collaboration among DFO Scientists to deliver sound advice in support of our priorities. The priority matrix (Figure 1) shows that several research priorities are being addressed by multiple COEs (in addition to research within the CCSI / ERIs). Thus, it is critical that overlap is identified and connectivity among activities is promoted to limit this overlap and maximize harmonization. Although this Plan provides a broad overview of our research activities in support of priority areas, DFO Scientists and Science Managers need to be

aware/informed of specific projects that they could contribute to, especially projects that are similar to COE (or CCSI / ERI) activities.

This Research Plan communicates our research priorities and approaches to achieving them from senior DFO Science managers to DFO Science staff. DFO Science will ensure all research projects maximize integration and harmonization with other DFO Science functions, especially its monitoring programs and collaborations with partners, and this will require substantial planning. The National Science Directors Committee (NSDC) will hold an annual meeting with COE Directors, ERI / CCSI leads that will include a review of the CCSI / ERIs / COEs to ensure this integration/harmonization and minimize gaps and overlaps. The results from this review will be communicated to the Scientists and Science Managers working on research as part of CCSI / ERI / COE activities. Further, our communication strategies will focus on maintaining open lines of communication about strategic direction, priority areas of research and linkages among CCSI / ERIs / COEs / other research activities. Clearly staff and managers need to remain informed, especially during periods of change.

Research conducted in support of the CCSI / ERIs / COEs address the highest priorities identified in the Research Agenda but it does not represent all of the ongoing research conducted within DFO Science. In order to fulfil mandated obligations, DFO Science is committed to its ongoing research programs that have been designed to provide advice to our clients in support of decision making. For example, DFO Science will continue to provide stock assessment advice to Fisheries and Aquaculture Management. However, this does not mean this research is not aligned with any of the ten research priorities outlined in the Five-Year Research Agenda. Rather, it shows that although the CCSI / ERIs / COEs will evolve into primary delivery mechanisms in support of ecosystem-based management over the coming years, other delivery mechanisms will continue to be used by DFO Science in support of its clients and evolving research or priority areas. DFO Science will continue to balance the need for stable, long-term science with the need for rapid, shorter-term science advice. By design, COEs will capture emerging issues within their areas of expertise and they have the flexibility to respond accordingly. Also, it is doubtful that any emerging issue would not be identified by at least one of our research activities but, if this were the case, it would be captured in the next Research Agenda and Research Plan, and could include development of a new COE (or other research initiative) to address the new topic.

4.3 How Research Will Be Conducted Under this Plan

In order to take charge of the change occurring within DFO Science, a teambuilding approach has been identified as the way forward for DFO Science with the creation of 20 research pieces to address departmental and federal priorities identified in the Research Agenda, including the CCSI, seven ERIs and 12 COEs. The resulting change includes a change in culture (with an emphasis on collaboration), governance, and communication strategies within DFO Science. The National Science Directors Committee (NSDC) will ensure research is aligned with objectives (including those of the CCSI / ERIs / COEs and

regional plans); develop relevant collaboration with partners; ensure regional and strategic funding is aligned to meet research objectives on a multi-years basis; and measure performance against objectives set for the CCSI / ERIs / COEs and regional plans.

Another prominent change in DFO Science's culture is an increased reliance on collaborative arrangements that can capitalize on both internal and external resources. The first step towards this end is to organize the research identified in this Plan around themes, either geographical, regional themes (i.e., ecosystems) or national themes developed around research priorities (i.e., climate change, invasive species, and energy production). By organizing scientists and support staff around a common theme, DFO Science ensures integration and harmonization of experience and expertise, regardless of where it resides. This teambuilding approach will support a culture of collaboration both within DFO Science and with outside collaborators in academia, non-governmental organizations, other federal or provincial departments, industry, and other nations. It is clear that DFO Science will depend more and more on external sources to deliver upon its commitments outlined in the Five-Year Research Agenda. In addition, our Collaboration Framework for DFO Science has been developed to ensure collaborations, including leveraging, will be successful and productive. This framework provides science staff with tools, including finance and policy information that will help establish successful collaborations with both governmental and non-governmental organizations. Having clear and transparent guidelines benefits both the department and our collaborators.

Furthermore, to ensure the success of these organizational changes, a change in governance structure is required. The modern governance structure utilized in COEs has proven effective. This governance structure that includes a director and regional membership on executive or steering committees is designed to balance regional and national priorities. This results in consistency and clear lines of accountability while remaining flexible enough to respond to emerging issues. A similar governance structure is planned for the CCSI and ERIs.

Our ability to effectively communicate internally and externally with clients, stakeholders, and partners is critical, especially during periods of change. To address this, DFO has developed a Strategic Science Outreach Strategy that will facilitate communication both within the Sector and to external audiences. Providing timely progress updates and maintaining clear lines of communication will ensure staff remain informed and contribute positively to the change occurring within DFO Science.

5.0 Conclusion

This Research Plan provides strategic direction on how effort and resources will be focused to ensure alignment with federal and departmental priorities while delivering on ecosystem-based management objectives. This Five-Year Research Plan addresses priorities identified in the Five-Year Research Agenda and supports the strategic direction outlined in the Science Framework for the Future. DFO Scientists should be able to

clearly identify how their specific research projects contribute to addressing priority areas, especially those identified through regional ERIs, or the national CCSI or COEs. Furthermore, this plan outlines some of the mechanisms Science Managers will need to implement to ensure Scientists within DFO Science can deliver the research required of them. It should be clear from reading this plan that DFO Science is committed to quality, ecosystem-based research in support of departmental and Government of Canada priorities and that the DFO Science program has retained the flexibility to respond to emerging issues. Although this Research Plan provides a broad overview of research conducted in support of priority areas, detailed, multi-year work plans have been developed for each of the 20 initiatives.

Appendix A: Lexicon for CCSI / ERIs / COEs.

Abbreviation	Full Name
CCSI	Climate Change Science Initiative
NLS	Newfoundland Shelf
GOM	Gulf of Maine
NOS	Northumberland Strait
LSLE	Lower St. Lawrence Estuary
LO	Lake Ontario
BSS	Beaufort Sea Shelf
SOG	Strait of Georgia
N-CAARE	National Centre for Arctic Aquatic Research Excellence
CEMAM	Centre of Expertise on Marine Mammals
CERP	Centre for Environmental Research on Pesticides
LEACA	Laboratories of Expertise in Aquatic Chemical Analysis
CHIF	Centre of Expertise on Hydropower Impacts on Fish And Fish Habitat
COOGER	Centre for Offshore Oil, Gas and Energy Research
CAHR	Centre of Expertise on Aquatic Habitat Research
CIAS	Centre for Integrated Aquaculture Science
CEARA	Centre of Expertise for Aquatic Risk Assessment
COMDA	Centre for Ocean Model Development and Application
CAAHRD	Centre of Expertise for Aquatic Animal Health and Research Diagnostics
CABRR	Centre for Aquatic Biotechnology Regulatory Research